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BRITISH COLUMBIA

Nesting Habitat of Marbled Murrelets on the Sunshine Coast

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INTRODUCTION

The Marbled Murrelet (*Brachyramphus marmoratus*), a tree-nesting seabird, is the focus of concern in British Columbia and the Pacific Northwest of the United States because of its apparent dependence on old-growth forests. It is federally listed as a threatened species (Rodway 1990) by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). In BC, the Marbled Murrelet is classified as a species at risk on the provincial "Red List" because it is threatened and is likely to face endangerment – thus potential extinction – if factors limiting its survival are not managed and reversed (Harper *et al.* 1994).

Factors considered in determining the status of the murrelet include: loss and fragmentation of nesting habitat; reduced availability of old-growth forests; the birds' low reproductive capacity (one chick per year per pair); movement (links) between populations; declining abundance (Kelson *et. al.* 1995); and threats at sea including oil spills (Piatt *et al.* 1990) and gill net fisheries (Carter and Sealy 1984). Southern populations (e.g., California) have declined and become isolated to a few disjunct areas that have remaining old forest nesting habitat (Ralph *et al.* 1995).

Little was known about the murrelet's use of forest habitat in BC until the last five years. Recent field research and inventories have filled in some of the information gaps, and BC's Forest Practices Code is providing new management direction. Efforts to maintain or recover murrelet populations in BC now focus on management of their nesting habitat, as stated in the Identified Wildlife Management Strategy (IWMS; Government of BC 1999).

This Extension Note summarizes recent work in south-coastal British Columbia and discusses implications for the future of the Marbled Murrelet. Its objectives are:

- to report the results of a recent research study on BC's Sunshine Coast, and compare them with other findings on habitat use by Marbled Murrelets in other locations;
- to describe the Marbled Murrelets' strong biological association with old-growth forests;
- to identify habitat features that are important to nesting Marbled Murrelets based on research conducted on the Sunshine Coast;
- to summarize potential forest habitat management practices for Marbled Murrelets.

LIFE HISTORY

The Marbled Murrelet is an alcid seabird (related to puffins) that inhabits nearshore coastal waters from Alaska as far south as central California (Ralph *et al.* 1995). It feeds primarily on small schooling fish and invertebrates (Carter and Sealy 1990, Burkett 1995). Although most species of alcids typically nest in dense colonies on offshore islands (Gaston and Jones 1998), the Marbled Murrelet nests inland in old-growth coniferous forests, and depends on the large limbs of mature conifer trees to provide structures broad enough to hold its nests.

The nesting season usually extends from April to August. Murrelets may fly up to 80 km inland from foraging areas to find a suitable nesting location; however, most known nests are within 30 km of foraging areas. Other factors being equal, nest locations close to the ocean are advantageous because energetic costs of flying to the nest are reduced and the chicks can be fed more frequently.

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Both members of a breeding pair take turns incubating their single egg, alternating every 24 hours during the 30-day incubation period (Nelson 1997). After hatching, the chick is left unattended at the nest while both adults bring single fish to feed it, up to eight times a day. Murrelet chicks are fed in this manner for 28 to 40 days before they fledge from the nest. When fledging, murrelet chicks make their initial flight at dusk from the nest to a marine foraging area. Murrelet chicks grounded accidentally on these flights are occasionally found stranded on the forest floor (Carter and Sealy 1987).

Researchers view the loss of nesting habitat as a major threat to Marbled Murrelet populations because it decreases their ability to recruit young into the population. Loss of nesting habitat may affect murrelets directly by causing increased mortality among breeding birds because they may be more exposed to predators if they travel further from foraging areas to their nests, or if they use low quality nest sites (Carter and Sealy 1987). As well, fragmentation of old-growth forest can result in some murrelets nesting at edges along roads and young plantations where they are more susceptible to disturbance and predation.

Murrelets in several locations have low nesting success due to a high frequency of predation (Nelson and Hamer 1995, Manley and Nelson 1999). Corvids – which include Common Ravens (*Corvus corax*) and Steller's Jays (*Cyanocitta stelleri*) – are often more abundant in edge habitats (Andren 1992) and they are common nest predators of murrelet adults, chicks, and eggs. Other predators of murrelet eggs and chicks include Northwestern Crows (*Corvus caurinus*), Gray Jays (*Perisoreus canadensis*) and, potentially, northern flying squirrels (*Glaucomys sabrinus*) (Marzluff *et al.* 1998). Common Ravens, Sharp-shinned Hawks (*Accipiter striatus*), Great Horned Owls (*Bubo virginianus*), Northern Goshawks (*Accipiter gentilis*), Peregrine Falcons (*Falco peregrinus*) and Bald Eagles (*Haliaeetus leucocephalus*) can prey on larger chicks and adults (Marks and Naslund 1994, Nelson and Peck 1995).

STUDY DESCRIPTION

This research study took place in the vicinity of Desolation Sound in the Sunshine Coast Forest District and included the Bunster Hills, a nesting area 5 km inland from Desolation Sound (Derocher *et al.* 1996). Additional data on murrelet habitat use were collected as part of an inventory of Marbled Murrelets on the Sunshine Coast being conducted by the BC Ministry of Environment, Lands and Parks. The Desolation Sound and Bunster Range areas were selected because:

- the marine waters of Desolation Sound are known to support high densities of Marbled Murrelets during the breeding season (Derocher *et al.* 1996); and
- the Marbled Murrelet population in the Strait of Georgia is considered at high risk because of the loss and fragmentation of old-growth forest in this area (Government of BC 1999).

Ground-based efforts to locate nest sites and monitor activity were concentrated in the Bunster Range. The area studied was limited to that accessible to researchers. The Bunster Range reaches a maximum elevation of 1,200 m and incorporates about 2,500 ha of old-growth forest, mostly above 800 m. In terms of biogeoclimatic zones, these forests fall within the Coastal Western Hemlock very wet maritime variant (CWHvm2) and Mountain Hemlock windward moist maritime variant (MHmm1; Meidinger and Pojar 1991). They are dominated by yellow cedar (*Chamaecyparis nootkatensis*), western hemlock (*Tsuga heterophylla*), Pacific silver fir (*Abies amabilis*) and mountain hemlock (*Tsuga mertensiana*).

The researchers located nest sites by following visual detections and vocalizations of birds recorded during standard dawn surveys (RIC 1995). They then climbed and searched trees after the breeding season to locate the nests (Manley 1999). A total of 52 nest trees of Marbled Murrelets were located using these methods. Habitat at nests was then sampled using four spatial scales – nest site (limb), nest tree, nest patch (0.02 ha around the nest tree) and nest stand, which is defined as a single forest cover polygon (see Figure 1, also Table 1).

These spatial scales were selected to represent a range of structures used by murrelets, from a fine scale (nest site) to a coarser scale that includes the forest characteristics around the nest (nest patch or stand). We are able to determine how these structures influence habitat selection using this multiple scale approach (Lertzman and Fall 1998). Generally, a habitat is considered selected by a species, at any scale, if use of the habitat is disproportionately greater than its availability (Neu *et al.* 1974, Manly *et al.* 1993).

HABITAT SELECTION WITHIN THE STAND

Murrelet nests were located on large-diameter limbs with epiphyte (usually moss) substrate and a high degree of overhead cover (Table 1). A large-diameter limb together with epiphyte cover provides a nesting platform for murrelets (Figure 1). This is a key structure for murrelets because they do not construct a nest and must find a platform in the tree canopy that is large enough and level enough to support their nesting attempt. Epiphytes on the platform may help to contain the egg and chick, as well as provide a warmer and drier microclimate. Large primary limbs with moss, the junction of primary and secondary limbs, mistletoe infestations or multiple leaders may offer suitable platforms.

We found that murrelets nested in large-diameter trees containing many potential nesting platforms (Table 1). Nest trees in the Bunster Range were among the largest-diameter trees available in the surrounding stand. These larger, older trees are superior for murrelets because they have more platform structures than smaller and younger trees. Yellow cedar was the predominant nest tree species in the Bunster Range. In this area, yellow cedar trees have more platforms and more epiphytes than other tree species at high elevation. Yellow cedar was also the most common large-diameter tree in the area searched for nests.

Murrelets preferred nest trees that were adjacent to canopy gaps (Table 1). Marbled Murrelets have a small wing area which assists them with diving and pursuing prey underwater, but as a consequence they must fly at high speeds (74 to 119 km/hr, Burger 1997) with rapid wingbeats to remain airborne. Canopy gaps are important for nest access because at these high flight speeds, murrelets approach the nest from below (often as low as 1-5 m above the ground) through a canopy gap in order to stall and land at the nest branch.

Nest patches had higher densities of large-diameter trees, lower densities of small-diameter trees, higher densities of platforms, and a higher proportion of platforms with moss pads than random patches (0.02 ha) of available habitat in the stand (Table 1). Selection for adjacency to a canopy gap did not result in murrelets using nest patches with less canopy cover (%) than the canopy

Table 1. Habitat features important to nesting Marbled Murrelets on the Sunshine Coast, British Columbia.

Spatial Scale		Habitat Features	Nest Sites Mean (range)	Occupied Stands Mean
Nest site	1.	Large diameter limbs	25 cm (11-62)	N/A
	2.	Large platform area	1230 cm^2	
	3.	Cover above the nest branch	75% (30-100)	
Nest tree	4.	Large dbh	100 cm (60-153)	N/A
	5.	Many potential nesting platforms	9 platforms (1-30)	
	6.	Yellow-cedar [1]	92% of nest trees	
	7.	Area of a canopy gap for access	267 m^2 (max. 418)	
Nest patch	8.	High density of platforms	128 platforms/ha (5-321)	N/A
	9.	High density of large dbh trees (>59 cm dbh)	53 trees/ha (10-147)	
	10.	Low density of small dbh trees (10-40 cm dbh)	521 trees/ha	
Nest stand	11.	High density of moss covered platforms	-	65.2 platforms/ha
	12.	High densities of yellow-cedar platforms	102 platforms/ha	55.0 platforms/ha
	13.	Canopy closure	71%	72%
	14.	Higher elevation	886 m (688-1260)	888 m

data are from 25-m radius fixed plots

[1]On the Sunshine Coast most remaining old-growth stands are at high elevation and contain yellow-cedar; other species of trees are used in other regions.

cover at the random patches of available habitat. Dense foliage in the nest patch canopy is important for hiding nests from predators, while the adjacent canopy gap is important for access. If nest sites are too open, their quality is diminished. For example, nest sites on forest edges have less canopy cover and experience higher nest failure due to predation than nests located in the interior of the stand (Hamer and Nelson 1995, Manley and Nelson 1999).

STAND LEVEL PATTERNS OF HABITAT USE

Occupied stands are those stands where murrelet behaviours associated with nesting are detected (RIC 1995). Stands occupied by murrelets on the Sunshine Coast were at higher elevations (>600 m), had higher densities of platforms and mossy platforms, and had less gap area in the canopy than stands where murrelets were not detected (Table 1). A higher density of platforms throughout the stand was the most important habitat feature for identifying stands selected by murrelets.

Marbled Murrelet activity was concentrated in higher elevation forests (>600 m). However, the research was inconclusive for determining preference for particular elevations because there was a limited availability of old-growth stands at low elevations. Relatively little activity was detected in the 15 low-elevation stands (including six mature second-growth stands) that were surveyed for murrelet activity (1995 to 1997), and these stands had lower densities of mossy platforms than higher-elevation stands (Manley 1999). Occupied stands occurred between 600 and 1200 m in elevation. Activity and proportion of occupied stands were greatest between 701 and 900 m, then decreased as elevation increased above 900 m (Manley 1999).

Although gaps adjacent to the nest tree are important for Marbled Murrelets, the types of stands selected by murrelets overall were more closed with a higher percentage of canopy cover than those not used by murrelets. More open stands, such as those in high-elevation parkland or in wet or rocky areas, appeared to provide lower-quality habitat for murrelets in this study area. These habitats may be more exposed to predators, have reduced availability of suitable platforms, or be influenced by undesirable microclimates.

FOREST EDGES AND NESTING MURRELETS

Only 33% of Marbled Murrelets nested successfully in the Bunster study area, and this low rate was mostly due to high rates of predation (86% of failed nests) likely attributable to Common Ravens and Steller's Jays (Manley 1999). During the study, seven murrelet nest trees were found on operational edges at roads or cutblocks. These nest trees were all large-diameter yellow cedar that were highly visible. Nests in these locations are easier for researchers to locate using visual surveys, and therefore do not represent the actual proportion of birds nesting on edges. We suggest that murrelets may use trees in these locations, even if these trees provide poorer habitat because of predators, if:

(1) the species has evolved behaviours in undisturbed ecosystems that adapted it for selecting highly visible and easily accessed nest trees;

(2) individuals show site fidelity; or

(3) there is limited availability of old-growth for nesting habitat.

Manley and Nelson (1999), using a sample of nests from the

Figure 1. *Nest patch, nest tree and nest site in yellow-cedar/mountain hemlock dominated stand. Photo at left (by Desolation Sound Research Project) shows nest patch; photo at right (by John Kelson) shows nest tree and nest site – note mossy platform at centre, with Marbled Murrelet chick partially visible on nest.*

Pacific Northwest (including the Sunshine Coast), report that nests located at or within 50 m of forest edges have lower nesting success (27%) and higher predation (60%) compared to those in the interior of the stand (>50 m).

Three of the seven nests at edges were used for more than one breeding attempt. The re-use of these nests in spite of their high rate of failure may be a further indication that these nest trees are attractive to murrelets in spite of the risks associated with them. Further research is needed to understand why murrelets use and sometimes re-use nest trees at edges.

HABITAT MANAGEMENT

At all spatial scales, Marbled Murrelets seemed to select most strongly for the number of platforms, which are a basic structural requirement of the nest. Murrelets also selected for the juxtaposition of cover at their nest and openings in their nest patch (Table 1). Yet the murrelets' selection for cover and openings varied with each spatial scale examined. These scales must be considered when managing for habitat features, particularly because throughout the range of the Marbled Murrelet there is considerable variation in the tree species and forest types that provide nesting structures.

Structural characteristics of stands and trees can be used to identify potential nesting habitat in areas where murrelets and their habitats have not been evaluated. For example, although murrelets nest in large-diameter old trees in most of their range (Table 2), a few nests have been found on the ground in southeastern Alaskan forests, and these nest sites and the surrounding nest patches are structurally similar to those found at nest trees. The ground nests were on moss pads on steep cliffs beneath a canopy of old forest that provided both cover for the nest and canopy openings for murrelets to access the nest site (DeGange 1996). It is important both in the short term and over the long term to maintain viable populations of Marbled Murrelets throughout their historic range, and this may include the restoration and recruitment of habitat.

MANAGEMENT PRACTICES TO MAINTAIN NESTING HABITAT

Given this research and other recent research (Table 2), we suggest the following management practices. The Identified Wildlife Management Strategy (Government of BC 1999) provides direction for managing the nesting habitat of Marbled Murrelets in landscape units subject to the Forest Practices Code.

1) Conserving Nesting Habitat

Maintain areas of habitat (Wildlife Habitat Areas, or WHAs) that are large enough to provide interior forest conditions and to reduce the predation risk for breeding populations as

Table 2. Results of habitat studies of Marbled Murrelets (MAMU) at coastal sites in the Pacific Northwest. (N=result from nest data, O=result from occupied activity, R=result from radar data)

	California	Oregon	Washington	British Columbia			Alaska
				Vancouver Island	Sunshine Coast	Queen Charlotte Isl.	
Select mossy platforms [1, 4]				O	N, O	O	N
Select large-diameter trees [1, 4]	O	N,O	N,O	O	N	O	N
Important tree species							
yellow-cedar					N		
mountain hemlock					N		N
western hemlock		N	N	O, N	N	O	
western redcedar			N	N	N	N	
Sitka spruce		N	N	O,N		O	N
Douglas fir	N	N			N		
coastal redwood	N						
Gap near nest tree for understory access of bird [3]					N		
High use of productive and moist site associations [3, 8, 9]				O	O	O	
More canopy cover in occupied compared to unoccupied forest stands [1, 6]	O				O		
More interior forest in stands with vs. without detections [6]	R	R					
Low-elevation old forest stands important habitat [3, 4, 6, 8, 10]	R	R		O, R		O	
Highest detections of MAMU in drainages with more old forest [7, 10]			R	R		O	
Successful nests close to tree trunk[1]	N	N	N	N	N		N
Lowest nest success at stand edge (<50 m) [1, 2, 5]	N	N	N	N	N		N
Predation main failure factor [1, 2, 3]	N	N	N	N	N		N
Nesting density comparison between sites [3, 4, 6]	Higher*	Higher*		Lower [4]	Higher [3]		
Multi-nest, multi-year trees	Yes	Yes	Yes	No [4]	Yes [3]		

**possibly higher but data inconclusive*

[1] Manley and Nelson 1999
[2] Manley and Blackburn 1999
[3] Manley 1999
[4] Chatwin *et al.* 1999
[5] Burger 1999a
[6] Meyer *et al.* 1999.
[7] Raphael *et al.* 1999.
[8] Rodway and Regehr 1998.
[9] Rodway *et al.* 1993.
[10] Burger 1999b

recommended in IWMS (Government of BC 1999).

The following features can be used to identify ***high quality*** habitats for WHAs:

a) Stands or patches will have high densities of suitable platforms.

b) High densities of large-diameter trees relative to those available in the stand/ecosystem – for example, trees at least >60 cm dbh and preferably >80 cm dbh in the CWHvm2 and MHmm1 variants – will be present.

c) Species of trees that provide the majority of platform structures in a given area will be present (the species used by murrelets vary among regions).

d) Stands in more productive sites with moisture regimes from moderate to very moist (Green and Klinka 1994) have higher densities of platforms and higher use by murrelets (Bahn 1998, Rodway and Regehr 1998, Manley 1999), relative to drier, less productive sites, because of the tree species, larger tree diameters and greater amounts of canopy epiphytes.

e) Stands with naturally occurring canopy gaps are preferred, although stands with small human-made gaps from earlier practices (e. g., old skid roads) may be acceptable. Natural gaps are often around streams or dead, broken or uprooted trees. Natural gaps generally do not occur until stands reach at least a mature successional stage.

f) Stands with moderate to high canopy closure (mean 70%) are preferred, while highly open stands (<50% mean canopy closure) such as those in the Mountain Hemlock Parkland subzone, and in areas dominated by bogs, wetlands and non-productive brush, are more likely to be avoided.

g) Low-elevation stands in several areas (Table 2) have more of the important habitat characteristics and higher use by murrelets than higher-elevation stands (Rodway and Regehr 1998). Stands at low elevation within 200 m of exposed coast (Coastal Western Hemlock southern very wet hypermaritime variant CWHvh1) are an exception because they appear to have low amounts of epiphytes, high exposure to wind, high predator densities and therefore low murrelet use (Rodway and Regehr 1998). Although sites at low elevations generally provide high-quality habitat (Table 2), in some areas, including the Sunshine Coast, sites at higher elevations provide important habitat used by murrelets.

h) Forest stands with minimum edges and maximum interior forest conditions are less prone to predation and other edge effects (e.g., edge effects are more prevalent in long narrow patches unless buffered by stands approximately >40 years). Stands of 200 ha are recommended in IWMS (Government of BC 1999).

The habitat quality of large dominant trees on existing edges is likely diminished but may be improved over the long term if immature forest adjacent to the trees is retained as a buffer. The habitat quality of large dominant trees on intended cutblock boundaries may be improved by adjusting the boundary to move

the edge away from these trees (>50 m).

2) Alternatives for Restoring or Recruiting Potential Murrelet Habitat

• ***Retained trees or patches:***

Several Marbled Murrelet nests in Washington and Oregon (Hamer and Nelson 1995), and a single nest recently discovered in Desolation Sound (F. Cooke pers. comm.), have been reported in small remnant patches of old-growth within mature second-growth forests. The success of murrelets using these nests is unknown, but the retention of nest trees as single trees or as small Wildlife Tree Patches (Government of BC 1995) within even-aged harvesting systems on shorter-term rotations (60-80 yr) does not appear to have immediate utility for nesting murrelets. Wildlife Tree Patches and single trees could potentially attract murrelets to nest in open, isolated habitats where they are more susceptible to predation because of their visibility on the nest platform.

However, if retained trees or patches persist over time and become buffered by sufficient regrowth, they may provide future nesting opportunities. Wildlife trees and patches are appropriate measures for stand level management of habitat only if larger patches of murrelet habitat have been effectively conserved at the landscape scale.

• ***Selective harvesting:***

Retention of trees with platforms and creation of canopy gaps used by murrelets may potentially be undertaken in old seral forest by applying single tree or group selection systems in uneven-aged stands. This approach would also maintain the high-percent canopy cover (e.g., 70% in the Bunster Range) characteristic of occupied stands (Hamer 1995, Kuletz *et al.* 1995, Ralph *et al.* 1995, Manley 1999). These silvicultural systems may be appropriate for some ecosystems on the coast where they can mimic natural disturbance patterns – for example, group selection in higher-elevation ecosystems (MHmm1) or wet coastal ecosystems (CWHvm1, CWHvm2) (Lertzman *et al.* 1996). In addition, retaining wildlife tree patches in more productive and moist sites, coupled with retaining riparian management areas within these stands, could more effectively protect key structures including large-limbed trees and epiphytes.

• ***Managing stand structure:***

Successional processes of stand structural development may potentially be accelerated in immature or mature stands, so that these stands acquire structural characteristics of late-successional stands used by murrelets (see IWMS, page 70):

a) Wide spacing promotes tree diameter growth (Oliver 1994), e. g., 500-1000 stems per ha with emphasis at the lower range;

b) Pruning promotes deep crowns for providing cover and large platform branches (Oliver 1994);

c) Trees infected with mistletoe can create platforms in young or mature trees (Hayes *et al.* 1997, Nelson 1997);

d) Selection systems can produce gaps that mimic natural stand openings, promote limb growth and stimulate platform development (Maguire *et al.* 1991, Hayes *et al.* 1997);

e) Old veteran trees in wildlife tree patches can provide large platforms;

f) Riparian buffers and management areas on smaller streams within stands will conserve naturally-associated canopy gap and established epiphytes; and

g) Alder or other deciduous trees (such as vine maple) in appropriate soils can act as natural gap makers.

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REFERENCES

Andren, H. 1992. "Corvid density and nest predation in relation to forest fragmentation: a landscape perspective," in *Ecology* 73:794-804.

Bahn, V. 1998. *Habitat Requirements and Habitat Suitability Index for the Marbled Murrelet (Brachyramphus Marmoratus) as a Management Target Species in the Ursus Valley, British Columbia.* MSc. Thesis, Philipps-Universitat, Marburg, Germany.

Burger, A.E. 1997. "Behaviour and numbers of Marbled Murrelets measured with radar," in *Journal of Field Ornithology* 68:208-223.

_____ 1999a. *Bird in Hot Water: Responses by Marbled Murrelets to Variations in Nearshore Ocean Temperature in British Columbia.* Oral presentation, Species at Risk Conference 1999, February 1999, Kamloops, BC.

_____ 1999b. *Radar Inventory of Marbled Murrelets in Clayoquot Sound, 1996-1998.* Report to Min. of Environ., Lands and Parks, March 1999.

Burkett, E.E. 1995. "Marbled Murrelet food habits and prey ecology," pp. 223-246 in *Ecology and Conservation of the Marbled Murrelet.* Eds. C.J. Ralph, G.L. Hunt, Jr., M.G. Raphael, and J.F. Piatt. US Forest Serv. Gen. Tech. Rep. PSW-152.

Carter, H.R., and S.G. Sealy. 1984. "Marbled Murrelet mortality due to gillnet fishing in Barkley Sound, BC," pp. 212-220 in *Marine Birds. Their Feeding Ecology and Commercial Fisheries Relationships.* Eds. D.N. Nettleship, G.A. Sangerand P.F. Springer. Spec. Pub., Canadian Wildlife Serv., Min. of Supply and Services.

_____ 1987. "Inland records of downy young and fledgling Marbled Murrelets," in *Murrelet* 68:58-63.

_____ 1990. "Daily foraging behaviour of Marbled Murrelets," in *Studies in Avian Biology* 14:93-102.

Chatwin, T.A., L.E. Jones, A.E. Burger, D. Newsom, and A. Mason. 1999. *Using Multi-scale Inventory and Research to Conserve Marbled Murrelets in Clayoquot Sound, British Columbia.* Oral presentation, Species at Risk Conference 1999, February 1999, Kamloops, BC.

DeGange, A.R. 1996. *A Conservation Assessment for the Marbled Murrelet in Southeast Alaska.* US Forest Service Gen. Tech. Rep. PNW-GTR-388.

Derocher, A.E., G.W. Kaiser, F. Cooke, I.A. Manley, and M.J. Gill. 1996. *Research on Marbled Murrelets in the Desolation Sound Area During the 1994 Breeding Season.* Canadian Wildlife Serv.

Tech. Rep. Ser. No. 257. Pacific and Yukon Region, Delta, BC.

Gaston, A.J., and I.L. Jones. 1998. *The Auks*. Oxford University Press, Oxford, UK.

Government of BC. 1995. *Biodiversity Guidebook*. Min. of Forests and Min. of Environ., Lands and Parks, Victoria, BC.

_____ 1999. *Managing Identified Wildlife: Procedures and Measures*. Min. of Forests and Min. of Environ., Lands and Parks, Victoria, BC.

Green, R.N., and K. Klinka. 1994. *A Field Guide to Site Identification and Interpretation for the Vancouver Forest Region*. Land Management Handbook 28, Min. of Forests, Crown Publications Inc., Victoria, BC.

Hamer, T.E. 1995. "Inland habitat associations of Marbled Murrelets in Washington," pp. 163-176 in *Ecology and Conservation of the Marbled Murrelet*. Eds. C.J. Ralph, G.L. Hunt, Jr., M.G. Raphael, and J.F. Piatt. US Forest Service Gen. Tech. Rep. PSW-152.

Hamer, T.E., and S.K. Nelson. 1995. "Characteristics of Marbled Murrelet nest trees and nesting stands," pp. 69-82 in *Ecology and Conservation of the Marbled Murrelet*. Eds. C.J. Ralph, G.L. Hunt, Jr., M.G. Raphael, and J.F. Piatt. US Forest Service Gen. Tech. Rep. PSW-152.

Harper, W., S. Cannings, D. Fraser, and W.T. Munro. 1994. "Provincial lists of species at risk," pp. 16-23 in *Biodiversity in British Columbia*. Eds. L.E. Harding and E. McCullum. Canadian Wildlife Serv., Delta, BC.

Hayes, J.P., S.S. Chan, W.H. Emmingham, J.C. Tappeiner, L.D. Kellog, and J.D. Bailey. 1997. "Wildlife responses to thinning in young commercial forests in the Pacific Northwest," in *Journal of Forestry* 95:28-33.

Kelson, J.D., I.A. Manley, and H.R. Carter. 1995. "Decline of the Marbled Murrelet in Clayoquot Sound 1982-1992," in *Northwestern Naturalist* 76:90-98.

Kuletz, K.J., D.K. Marks, N.L.Naslund, N.J. Goodson, and M. Cody. 1995. "Inland suitability for the Marbled Murrelet in south-central Alaska," pp. 141-150 in *Ecology and Conservation of the Marbled Murrelet*. Eds. C.J. Ralph, G.L. Hunt, Jr., M.G. Raphael, and J.F. Piatt. US Forest Service Gen. Tech. Rep. PSW-152.

Lertzman, K.J., and J. Fall. 1998. "From forest stands to landscapes: spatial scales and role of disturbances," pp. 339-367 in *Ecological Scale: Theory and Applications*. Eds. D. Peterson and V.T. Parker. Columbia University Press, Columbia, OH.

Lertzman, K.J., G.D. Sutherland, A. Inselberg, and S.C. Saunders. 1996. "Canopy gaps and the landscape mosaic in a coastal temperate rainforest," in *Ecology* 77:1254-1270.

Maguire, D.A., J.A. Kershaw, and D.W. Hann. 1991. "Predicting the effects of silvicultural regime on branch size and crown wood core in Douglas-fir," in *Forest Science* 37:1409-1428.

Manly, B.F., L.L. McDonald, and D.L. Thomas. 1993. *Resource Selection by Animals (Statistical Design and Analysis for Field Studies)*. Chapman and Hall, London, UK.

Manley, I.A. 1999. *Behaviour and Habitat Selection of Marbled Murrelets Nesting on the Sunshine Coast*. MSc. Thesis, Simon Fraser University, Burnaby, BC.

Manley, I.A., and I. Blackburn. 1999. *Effects of Forest Edge and Canopy Cover on the Detection and Nesting Ecology of Marbled Murrelets*. Oral Presentation, Species at Risk Conference 1999, February 1999, Kamloops, BC.

Manley, I.A., and S.K. Nelson. 1999. *Habitat Characteristics Associated with Nesting Success and Predation at Marbled Murrelet Nests*. Abstract. Pacific Seabird Group 26th Annual Meeting, Feb. 25-29, 1999, Blaine, WA.

Marks, D.K., and N. L. Naslund. 1994. "Sharp-shinned hawk preys on a Marbled Murrelet nesting in old-growth forest," in *Wilson Bulletin* 106:565-567.

Marzluff, J.M., M.G. Raphael, J.M. Luginbuhl, J.E. Bradley, and S.P. Courtney. 1998. *Habitat Correlates of Marbled Murrelet Nest Predators: Stand Versus Landscape Attributes*. Pacific Seabird Bulletin 1998.

Meidinger, D., and J. Pojar, eds. 1991. *Ecosystems of British Columbia*. Min. of Forests, Research Branch, Prov. BC Spec. Rep. Series No. 6. Crown Publications Inc., Victoria, BC.

Meyer, C.B., S.L. Miller, and C.J. Ralph. 1999. *Marbled Murrelet Use of Landscapes for Nesting in California and Southern Oregon*. Oral Presentation, Pacific Seabird Group 26th Annual Meeting, Feb. 25-29, 1999, Blaine, WA.

Nelson, S. K. 1997. "Marbled Murrelet: *Brachyramphus marmoratus*," pp.1-32 in *The Birds of North America. No. 276*. Eds. A. Poole and F. Gill. The American Ornithologists' Union. Washington, DC.

Nelson, S.K., and T.E. Hamer. 1995. "Nest success and the effects of predation on Marbled Murrelets," pp. 89-98 in *Ecology and Conservation of the Marbled Murrelet*. Eds. C.J. Ralph, G.L. Hunt, Jr., M.G. Raphael, and J.F. Piatt. US Forest Service Gen. Tech. Rep. PSW-152.

Nelson, S. K., and R.W. Peck. 1995. "Behavior of Marbled Murrelets at nine nest sites in Oregon," in *Northwestern Naturalist* 76:43-53.

Neu, C.W., C.R.Byers, and J.M. Peek. 1974. "A technique for analysis of utilization and availability data," in *Journal of Wildlife Management* 38:541-545.

Oliver, C.C. 1994. "Silvicultural opportunities for creating high quality wood and other values," pp. 43-61 in *High Quality Forestry Workshop: the Idea of Long Rotations, Silver Falls State Park, Oregon, May 10-12, 1993*. J.F.Weigand, R.W. Haynes, and J.L. Mikowski, compilers. College of Forest Resources, U. of Washington, Seattle, WA.

Piatt, J.F., C.J. Lensink, W. Butler, M. Kendziorek, and D.R. Nysewander. 1990. "Immediate impact of the Exxon Valdez oilspill on marine birds," in *Auk* 107:387-397.

Ralph, C.J., G.L. Hunt, M.G. Raphael, and J.F. Piatt. 1995. "Ecology and conservation of the Marbled Murrelet: an overview," pp. 3-22 in *Ecology and Conservation of the Marbled Murrelet*. Eds. C.J. Ralph, G.L. Hunt, Jr., M.G. Raphael, and J.F. Piatt. US Forest Service Gen. Tech. Rep. PSW-152.

Raphael, M.G., D.M. Evans, and B.A. Cooper. 1999. *Correlating Forest Habitat Distribution with Murrelet Radar Counts: Is There a Connection at the Drainage Scale?* Oral Presentation, Pacific Seabird Group 26th Annual Meeting, Feb. 25-29, 1999, Blaine, WA.

RIC (Resources Inventory Committee). 1995. *Standardized Inventory Methodologies for Components of British Columbia's Biodiversity: Marbled Murrelets in Marine and Terrestrial Habitats*. Min. of Environ., Lands and Parks, Victoria, BC.

Rodway, M.S. 1990. *Status Report on the Marbled Murrelet in Canada*. Committee on the Status of Endangered Wildlife in Canada Report. MacMillan Bloedel Ltd. and Mininistry of Environ., Lands and Parks, Victoria, BC.

Rodway, M.S., and H.M. Regehr. 1998. "Inland inventory: Marbled Murrelet activity and structural characteristics of old-growth forest in Clayoquot Sound, 1995-1997," pp. 119-175 in *Inventory of Marbled Murrelets in Clavoquot Sound 1997*. Eds. T.A. Chatwin, A.E. Burger, and L.E. Jones. Unpublished report to Min. of Environ., Lands and Parks, Vancouver Island Regional Office, Nanaimo, BC.

Rodway, M.S., H.M. Regehr,, and J.P.L. Savard. 1993. "Activity levels of Marbled Murrelets in different inland habitats in the Queen Charlotte Islands, BC," in *Canadian Journal of Zoology* 71:977-984.